

Building Pressure Control in VAV Systems with Relief Air Fan

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Abstract

Building pressure control is critical to energy conservation and indoor air quality by preventing excessive infiltration or exfiltration. In the supply and the return/relief fan Air Handling Unit (AHU) system, better space pressurization can be achieved when return/relief fan operates properly in response to the supply fan. In this paper, a motor power based fan air flow station was developed in a real case to obtain better building pressure control by supply and relief fan-tracking. The detail of the motor power based fan air flow station setup was provided. The building walk-through investigation shows the improvement in building pressure control.

Introduction

Space pressurization is a key issue in building energy savings and indoor air quality control, even the safety. In the humid area, the negative building pressure will result in the mold so that damage the building envelope. In the return/relief fan AHU system, acceptable space pressurization can be achieved if the return/relief fan operates properly in response to the supply fan. Compared with the constant volume system, VAV system has much more challenges in the supply and return/relief fan-tracking. The most common fan-tracking methods are listed below.

Slave return/relief fan control

In this method, the return/relief fan modulates its speed in proportion to the supply fan speed change. Because of the totally different system curve and fan curve of the supply and return/relief fans, this method leads to poor fan-tracking thus resulting in bad space pressurization [1].

Space pressure control

In this method, the return/relief fan modulates to maintain a space pressure set point. However, this method often proves impractical because of the difficulty in measuring the very low space pressure [1].

Airflow monitor

In this method, the airflow monitors have been located in the exhaust and outside air duct, and the return/relief fan modulates to maintain a constant differential air flow rate between the outside air intake and the exhaust. The drawbacks of this method are the cost and the difficulty in finding a section of ductwork with limited turbulence to install the monitors [1].

Plenum pressure control method

There are two versions of this method.

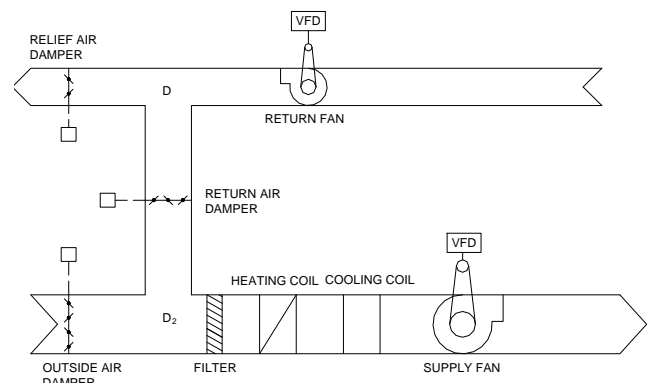


Figure 1 AHU with return fan

Fixed-plenum-pressure method: As can be seen in Figure 1, the return/relief fan is modulated to maintain a constant pressure D , which is determined by air balance testing to allow full required exhaust air flow to exit the building. The mixed air damper is controlled to maintain a constant pressure D_2 , which is setting according to air balance measurement that provides full required outside air intake. The outside air damper is controlled to maintain a mixed air set point, while the exhaust air damper is modulated to exit the correct air flow from the building. The drawback of this method is the potential energy waste resulted from the fixed plenum pressure that is higher than the real needed when the outside and exhaust dampers are partially open [1].

Fixed-damper method: The fixed-damper method has been developed based on the intuitive solution to overcome the energy waste of the fixed-plenum-pressure method. Instead of

modulating the outside air and exhaust damper, this method controls the outside air intake and exhaust air by applying a reset schedule for plenum pressure D and D_2 while both dampers keep fully open. However, this method also has two disadvantages. One is that the full open outside air damper regardless of flow will increase the risk of coils freezing. Another is that when the outside air intake reduces, the pressures maybe decrease to a level that the pressure sensor cannot provide the enough accuracy [1].

Fan air flow station methods

Instead of using the airflow monitor, Liu developed the fan head based airflow station, which determines the airflow using the measured fan speed, the fan head, and the in-situ fan curve [2]. The measured airflow data matched the fan airflow station value very well [3]. However, it has poor accuracy when the fan speed is low [4]. To overcome this limitation, recently, Wang and Liu developed a motor power based fan airflow station., which determines the fan airflow using the measured fan motor power, the fan speed or control system command to VFD, and the in-situ fan motor power curve. Since the fan power measurement has much higher accuracy than the fan head, this method has better accuracy than the fan head based fan airflow station for certain type of fans. The implementation cost can also be lower than the fan head based fan airflow station since fan power can be obtained directly from VFD [5].

The motor power based fan airflow station method can be applied to the fan-tracking to perform a better building pressurization. The theory of the motor power based fan airflow station can be referred to [5]. This paper provides the detail information of the application of this method in a real building.

Building Information

The east wing of the building served by one VAV air handling unit with VFDs on the supply and relief fans was investigated. As can be seen in figure 2, the supply fan was controlled to maintain the static pressure set point, while the relief fan was modulated in response to the building pressure. However, the limitation of the relief fan control algorithm results in some building pressure control problems.

During economizer period, when outside air intake is large, especially 100% outside air intake, some exterior doors can not fully close by itself, although the building pressure sensor reading is around 0.02 inch w.g. Moreover,

undesirable “wind” occurred at the connection linking the east wing and the west wing, which was served by heat pump systems and had acceptable building pressure.

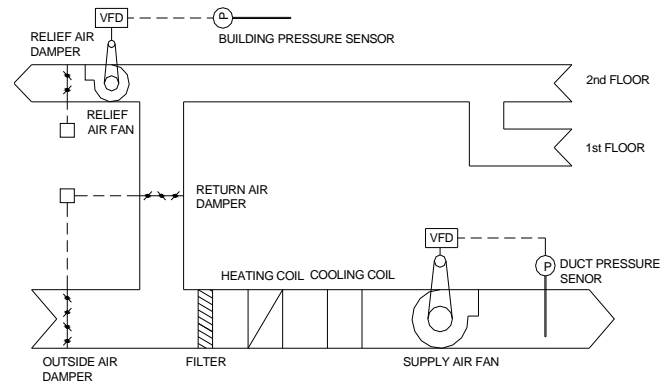


Figure 2 Schematic of AHU

Methodology and Implementation

To solve those problems listed above, a new building pressure control strategy was applied. Relief fan air flow, supply fan air flow and outside air flow are needed to implement the new building pressure control strategy. During non-economizer period, the outside air damper operates at its minimum position. Notice that it is not a big AHU with a designed supply air flow of 40,000CFM, the relief damper and relief fan can be shut off during non-economizer period without causing any building pressure problem.

During economizer period, The relief and supply fan air flow can be obtained from the motor power based fan air flow station, which uses the motor power and VFD speed to calculate the fan air flow based on a full speed measured fan motor power curve. Based on the economizer operation, the outside air flow can be correlated with supply fan air flow, outside air temperature, supply air temperature and return air temperature. When the outside air flow is available, a relief air flow set point can be determined. Then, a PI control loop can use to modulate the relief fan VFD to achieve the relief air flow set point.

Relief fan air flow

The relief fan motor power from the VFD output was introduced to the central control computer, while the motor speed is available in the central computer as an output signal. To measure the full speed relief fan motor power curve, change the relief fan VFD speed in the central computer from low limit to the full speed, and record both the speed and motor power data in the central computer. According to fan laws,

these motor power data under different VFD speeds can be converted to corresponding motor power point at full speed. Therefore, a measured full speed fan motor power curve was obtained, as shown in Figure 3. From this curve, we can get the equation:

$$W_{r,d} = -0.4432Q_{r,d} + 35.816 \quad [1]$$

Where, $Q_{r,d}$ = full speed relief air flow, CFM,

$W_{r,d}$ = full speed relief fan motor power, kW.

Based on fan laws, we have

$$\frac{Q}{Q_{r,d}} = \frac{\omega}{\omega_{r,d}} = \varpi \quad [2]$$

$$\frac{W}{W_{r,d}} = \left(\frac{\omega}{\omega_{r,d}} \right)^3 = \varpi^3 \quad [3]$$

Where, Q = partial load fan air flow, CFM,

W = partial load fan motor power, kW,

$\omega_{r,d}$ = VFD full speed, 60Hz,

ϖ = partial load VFD speed ratio.

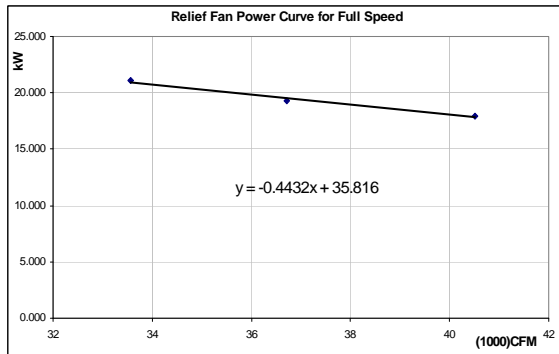


Figure 3 Relief fan power curve at full speed

Substituting equations (2) and (3) into (1) and rearranging, the relief fan air flow under partial load can be calculated by

$$Q_r = \frac{W_r}{(\varpi_r)^2} - 35.816 \cdot \varpi_r \quad [4]$$

Where, W_r = relief fan motor power, kW,

Q_r = relief fan air flow, CFM,

ϖ_r = relief fan speed ratio.

Supply fan air flow

Same as relief fan air flow, using the supply fan motor power curve shown in Figure 4, the supply fan air flow under partial load can be calculated by

$$Q_s = \frac{\frac{W_s}{(\varpi_s)^2} - 35.262 \cdot \varpi_s}{-0.243} \quad [5]$$

Where, W_s = supply fan motor power, kW,

Q_s = supply fan air flow, CFM,

ϖ_s = supply fan speed ratio.

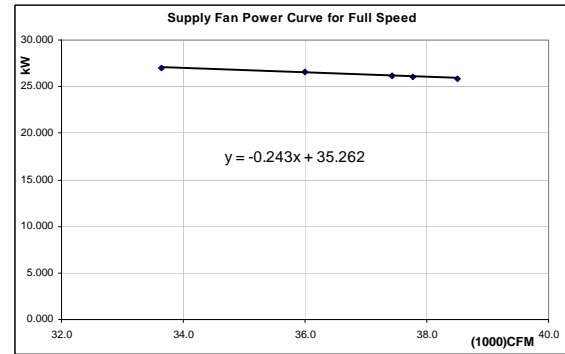


Figure 4 Supply fan power curve at full speed

Outside air flow

When outside air temperature is between 55°F and 68°F, the outside air damper will be full open and the mixed air damper full close.

Therefore, the outside air flow will be equal to supply fan air flow.

When outside air temperature is lower than 55°F, the AHU operates at “free cooling” mode. Hence, the outside air flow can be calculated by

$$Q_{OA} = \frac{Q_s \cdot (T_R - T_S)}{T_R - T_{OA}} \quad [6]$$

Where, T_{OA} = outside air temperature,

T_R = return air temperature,

T_S = supply air temperature.

When outside air temperature is higher than 68°F, the AHU will operate at non-economizer mode, and the relief fan and relief damper will be shut off. Table 1 summary the outside air flow calculation.

Table 1 Outside air flow calculation

Outside air temperature	Outside air flow value
55°F < T_{OA} ≤ 68°F	$Q_{OA} = Q_s$
T_{OA} ≤ 55°F	$Q_{OA} = \frac{Q_s \cdot (T_R - T_S)}{T_R - T_{OA}}$ <p>When economizer reaches its minimum position, shut off the relief fan.</p>
T_{OA} > 68°F	The relief fan was shut off.

In order to pressurize the building appropriately, the relief air flow should be slightly less than the outside air intake. This value needs to be evaluated by field investigation. In this building, outside air flow needs to be 2300 CFM more than the relief air flow. Therefore, a relief air flow set point is calculated by

$$Q_{r,sp} = Q_{OA} - 2300 \quad [7]$$

Where, $Q_{r,sp}$ = Relief air flow set point, CFM.

A PI control loop will be applied to modulate the relief fan VFD speed to maintain this relief air flow set point.

Results

After this control strategy was implemented in Mar. 2005, the building pressure control in east wing of this building has improved a lot. Those exterior doors can close smoothly and the undesirable “wind” has disappeared. Figure 5 and 6 provide a 24-hour AHU operation data for the fan power air flow station. As can be seen in these two figures, the relief fan can follow the supply fan trend very well.

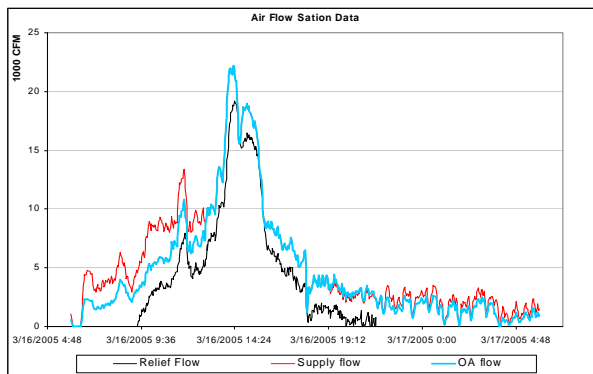


Figure 5 Fan power air flow station operation data

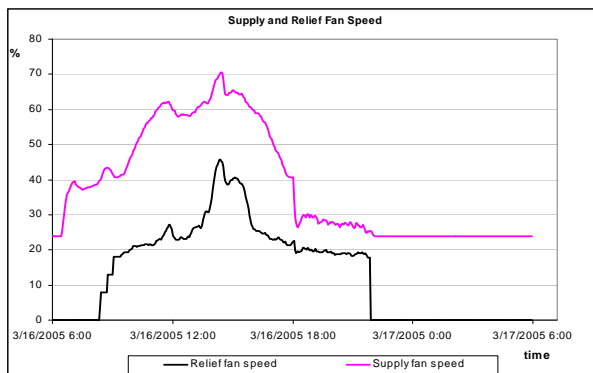


Figure 6 Supply and relief fan speed

Conclusion

Good building pressure control can be achieved by applying this control strategy. Compared with building pressure based relief fan control scheme, this method has less cost and better result

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